frontiers | Frontiers in Education

TYPE Conceptual Analysis
PUBLISHED 10 November 2022
DOI 10.3389/feduc.2022.995865

OPEN ACCESS

EDITED BY
Christoph Kulgemeyer,
University of Bremen, Germany

REVIEWED BY
Consuelo M. Kreider,
University of Florida, United States
Dorota Podgórska-Jachnik,
University of Łódź, Poland

*CORRESPONDENCE
Maria Chrysochoou
maria.chryosochoou@uconn.edu

SPECIALTY SECTION
This article was submitted to STEM Education, a section of the journal Frontiers in Education

RECEIVED 16 July 2022
ACCEPTED 26 October 2022
PUBLISHED 10 November 2022

CITATION
Chrysochoou M, Zaghi AE and Syharat CM (2022) Reframing neurodiversity in engineering education.
Front. Educ. 7:995865.
doi: 10.3389/feduc.2022.995865

Reframing neurodiversity in engineering education

Maria Chrysochoou*, Arash E. Zaghi and Connie Mosher Syharat

Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT, United States

A growing body of literature suggests that neurodiverse learners may possess assets that are highly desirable within engineering disciplines. Even so, despite the potential of neurodiverse individuals to contribute to innovation in science and engineering, neurodiverse students, such as those with attention deficit hyperactivity disorder (ADHD), autism, or dyslexia, remain highly underrepresented in engineering majors. We argue that the predominant perception of neurodiversity as a disability limits the participation of neurodiverse students in engineering education, ultimately impacting the diversity and creativity of the engineering workforce. In this paper, we review the emerging literature on neurodiversity that takes a social ecology approach and moves away from deficit-based models. We then describe the potential benefits and challenges of neurodiversity in the context of engineering education. We conclude with a concept analysis of how a strengths-based perspective of neurodiversity may be integrated within engineering education in particular, as well as in higher education overall, as we present our vision for a transformative education system that moves beyond mere accommodation of learning differences and empowers all students to leverage their unique strengths. In presenting a strengths-based approach to neurodiversity, we aim to contribute to a paradigm shift that transforms how university faculty and staff understand and perceive neurodiversity, improves the educational experiences of neurodiverse students in higher education and enhances the creativity of the engineering workforce.

KEYWORDS

neurodiversity, engineering education, innovation, ADHD, autism, dyslexia

Introduction

Neurodiverse students, such as those with attention deficit hyperactivity disorder (ADHD), autism, or dyslexia, remain highly underrepresented in engineering majors. One sample of college students with ADHD showed that only 3% were enrolled in engineering (Sparks et al., 2004) and one sample of autistic students showed that while 34% were enrolled in STEM fields, only 5% were enrolled in engineering (Wei et al., 2017). Rather than attribute this underrepresentation to structures within engineering education that may limit the participation of neurodivergent students, this underrepresentation is often explained *via* deficit-based myths and misperceptions about the *ability* of neurodivergent students to learn engineering and STEM concepts and skills, such as mathematics (Martin et al., 2011; Lambert, 2018). However, there is no evidence to suggest that neurodiverse individuals lack the cognitive skills required to succeed as an engineer. On the contrary, a growing body of literature suggests that neurodiverse learners may possess assets like divergent thinking, strong visual-spatial skills, systems thinking, intuition and insightfulness, and pattern recognition that are highly desirable for innovation and productivity in engineering (von Karolyi, 2001; White and Shah, 2006; Mottron, 2011; Meilleur et al., 2015; Taylor et al., 2020). As individuals with years of experience both teaching engineering topics, working closely with neurodiverse engineering students, and conducting engineering education research, we believe that the predominant characteristics of the post-secondary education system render engineering education less accessible to and impede the academic success of neurodiverse learners. While our work is based in the United States, the literature and our own experience indicates that these ideas and practices are generalizable in higher education globally.

In presenting a strengths-based approach to neurodiversity in the context of engineering education, we aim to contribute to a paradigm shift that transforms how university faculty and staff understand and perceive neurodiversity, improves the educational experiences of neurodiverse students in higher education and enhances the creativity of the engineering workforce. Moreover, these changes promise to enhance learning for a wide range of students who may all benefit from an educational paradigm that values and capitalizes on cognitive differences, incorporates varied and accessible pedagogy, and presents flexibility that allows learners to cultivate their strengths in the context of their engineering coursework. We believe this shift is crucial if engineers are to continue to lead in innovation and help address the complex and multifaceted problems faced by society.

In this article, we employ a concept analysis method. We first briefly review the literature on neurodiversity with an emphasis on the latest theoretical paradigms. We then describe the potential benefits and challenges of neurodiversity in the context of engineering education. We conclude with a discussion of how a strengths-based conceptualization of neurodiversity may be integrated in the higher education system.

Methodology

Concept analysis approach

Concept analysis is a form methodology intended to explore and clarify an abstract theory (Walker and Avant, 1995). "The results of concept analysis yield to the theorist or investigator a basic understanding of the underlying attributes of the concepts. This helps to clearly define the concept and to allow the investigator or theorist to construct statements or hypotheses that accurately reflect the relationships between the concepts" (Walker and Avant, 1995). Walker and Avant (2005) describe an eight-step procedure: select a concept; determine the purpose of the analysis; identify all uses of the concept; determine its defining attributes; identify a model case; identify borderline, related, and/or other cases; identify antecedents and/or consequences; and define the empirical referents. These steps need not be sequential; we take an iterative path in this study. As described in the introduction, defining the concept of the strength-based model is an important first step in creating a paradigm shift in STEM education away from the deficit model. This study presents a strengths-based approach toward neurodiversity in STEM education. Because of the prevalence of the traditional disability lens, our search of the literature yielded a great deal of evidence toward our contrary concept, the deficit model. Our findings therein are elaborated below in the Neurodiversity section. Walker and Avant note that defining a concept's attributes is the core function of the concept analysis method and thus a majority of the paper attempts to do so, with model cases used to better-contextualize each identified attribute. We conclude by exploring what future research and application of our strengths-based model of STEM education may yield.

Reflexivity statement

Reflexivity is critically important in any qualitative research. "Reflexivity is our best tool for understanding our strengths and our limitations, but also for recognizing our implicit values and assumptions" (Braun and Clarke, 2022). As such, we have taken careful consideration of our internal biases and worldviews and identify them here in the spirit of validity and good research. Two co-authors are tenured professors within the engineering field, one of whom has a formal diagnosis of ADHD. One co-author is a neurodiverse Ph.D. student in education who also has experience working with neurodiverse undergraduate and graduate students in STEM fields. While we believe our proximity and firsthand experiences allow the authors keen

insights, we understand it may also cloud judgment because of unconscious and implicit biases. To mitigate this, we have employed the formal concept analysis framework to ground our intuitions in data and process. Moreover, a colleague versed in qualitative methods reviewed this study and assisted in further acknowledging any incidents of potential bias.

Conceptual antecedent: Neurodiversity in the deficit-based model

Neurodiversity is a term that encompasses a wide range of neurological differences leading to distinct cognitive characteristics that are categorized as ADHD, autism, dyslexia, generalized anxiety disorder (GAD), dysgraphia, dyscalculia, and other learning differences. These naturally occurring neurological variations that are present within any sample population in the world are widely labeled and understood as disabilities (Armstrong, 2017). The term neurodiversity was coined by Australian sociologist Judy Singer, a self-identified autistic woman, who wrote:

The word disability itself is problematic. It just doesn't fit . . . The word disability comes from the pre-quantum era, with its discrete boundaried polar opposition between "able" and "disabled," and fails to encapsulate the situation of people on the spectrum. The word has too much stigma attached despite the efforts of the disability rights movement to reclaim it. . . (Singer, 1998, p. 25–26).

Since the neurodiversity paradigm has, for the most part, been championed by a subset of those on the autism spectrum (Judy Singer, for example), some believe that it may not fully represent the experience of those who may be less able to engage in self-advocacy or who have experienced autism as a disabling condition rather than an integral part of their identity (den Houting, 2019). Of course, this lack of representation also extends to neurodiverse individuals, such as those with ADHD or dyslexia whose experiences are often not a part of the larger conversation on neurodiversity. The concept of neurodiversity is not always clearly defined, and sometimes, definitions are contradictory in nature, given that the neurodiversity paradigm rejects the medical model for its pathologizing of naturally occurring neurological difference, but also may rely on medical diagnosis for access to support and inclusion in the neurodiversity community (Russell, 2020). Even today, the concept of neurodiversity has been critiqued by some for creating a narrative that sugarcoats the challenges that come with neurological differences (Dwyer, 2022).

Despite years of activism within the autism and wider neurodiversity movements, these natural cognitive variations continue to be understood primarily through a medical lens, which defines them as disorders or deficits that should be remedied through treatment rather than be recognized as a part of human diversity and valued as such (Haney, 2018). While we advocate for a strengths-based approach to neurodiversity, we acknowledge that there are challenges for many, especially within higher education. We also acknowledge that some individuals experience their neurodiversity as a disability. Also, the authors do not intend to portray neurodiverse individuals as superhumans with superior cognitive abilities. Throughout this paper, we have chosen to use the term "neurodiverse" rather than "neurodivergent," despite its grammatical incongruence, as we aim to emphasize the benefits of neurological diversity, rather than accentuate the divergence of some students from the perceived "norm."

Decades after Singer wrote her thesis, many neurodiverse college students still struggle to feel that they belong, particularly in engineering and other STEM fields; the stigma related to a disability label leads many to keep quiet about their diagnosis. While it is difficult to determine the exact number of students who choose to not disclose their diagnosis within the context of higher education, the numbers are likely quite significant. One study reported that while 94% of students with learning disabilities received supports in high school, only 17% receive these accommodations in post-secondary education (Cortiella and Horowitz, 2014). Similarly, another study found that only 16.6% of participants who were formally diagnosed with ADHD were receiving services from the university's Center for Students with Disabilities (Zaghi et al., 2016). This lack of disclosure is in large part due to the stigma that students believe they will face from peers and faculty (Barnard-Brak et al., 2010; Smith et al., 2021) who may hold negative attitudes related to students with disability labels and who often perceive accommodations as an unfair advantage (McCarron, 2017). Despite the legal protections provided by the Americans with Disabilities Act (ADA), many neurodiverse students report experiencing discrimination and negative messaging from faculty; some are discouraged from pursuing their chosen field or using their accommodations (Ehlinger and Ropers, 2020). The stigma and stereotype threat associated with these labels not only leaves many neurodiverse students without the accommodations that may facilitate their learning, but may also negatively impact psychological wellbeing (for example, increased anxiety and depression symptoms) and academic performance (Haft and Hoeft, 2021). Ultimately, the disability-based approach may have the unintended consequence of impeding their academic success, professional advancement, and personal fulfillment.

This impediment is all the more pronounced within the conventional engineering curriculum. Engineering education programs are often characterized by their narrow focus on and rigid adherence to standardized ways of thinking and problem solving and traditional modes of instruction and assessment (Baumol, 2005; Kazerounian and Foley, 2007). In a field that has been slow to adopt teaching innovations such as active, hands-on, cooperative, or problem-based learning, this means

that classroom instruction in many schools of engineering often relies on passive learning *via* lecture (Golter et al., 2012). This one-size-fits-all model of teaching and learning not only limits opportunities for neurotypical learners to engage in interactive learning and creative problem solving, but it also notably fails neurodiverse students some of whom possess strengths in these areas. While accommodations such as extended time on exams and assistance with note-taking may level the playing field for some students (Moon et al., 2012; Zaghi et al., 2016; Goegan and Harrison, 2017), they fail to address the underlying mismatch between the unique abilities of neurodiverse students and the demands of the traditional educational environment (Zaghi et al., 2016). As it stands, the current engineering education system does very little to acknowledge the strengths of many neurodiverse learners (Zaghi et al., 2016; Armstrong, 2017).

Antecedents in neurodiversity literature and the strengths-based model

In contrast to the medical model of disability, which casts neurological variations as problematic deviations from a perceived norm, the neurodiversity paradigm acknowledges the difficulties faced by neurodiverse individuals in society because of underlying assumptions and structures, but also challenges rigid definitions of normal and emphasizes the unique abilities and strengths related to cognitive diversity (Brown et al., 2021). Clouder et al. (2020) write that the "use of the term, neurodiversity, focuses on differences in individual brain function and behavioral traits, regarded as part of normal variation in the population" and suggests that though there are challenges associated with neurodiversity, "many neurodiverse conditions bestow talents or benefits" that are often not acknowledged, particularly in higher education settings, due to the predominant focus on student deficits (p. 758). The current literature related to neurodiversity indicates that ADHD may be associated with divergent thinking and risk-taking (White and Shah, 2016; Zaghi et al., 2016), dyslexia is often related to strengths in 3-dimensional visualization (von Karolyi, 2001; Attree et al., 2009; Diehl et al., 2014; Daniels and Freeman, 2018), and autism is associated with a strong understanding of systems and abilities in pattern identification (Bouvet et al., 2016; Austin and Pisano, 2017; Crespi, 2021). Beyond the harm that a deficit view may inflict on individuals deemed deficient or lacking, some scholars suggest that an over-emphasis on deficits and the medicalization of neurodiversity may in fact limit our ability to make scientific progress toward understanding neurodiverse conditions as a key part of our full human potential (Dinishak, 2016).

Emerging models of neurodiversity seek to move beyond the medical and social models of disability by taking a multidisciplinary approach that acknowledges the biological and psychological underpinnings of neurodiversity within the context of a broader social ecology. Doyle's (2020) work suggests that neurominorities (i.e., the 15–20% of a given population who fall under the neurodiversity umbrella) may either be disabled and excluded by the social structures that are largely constructed around the needs and abilities of the "neurotypical" majority or may thrive within an inclusive environment that allows for neurodiverse individuals to use their strengths both for their own benefit and for the benefit of society. While Doyle's focus is on neurodiversity in the context of the working world, there are implications for the education system, as well. An increasing number of large companies within the tech sector, including Hewlett Packard Enterprise (HPE) and Microsoft, have recognized the need for the unique talents of neurodiverse workers and have launched targeted recruiting efforts, with many centered around the strengths of autistic individuals whose unique perspectives, strong work ethic, and above-average abilities in memory, mathematics, or pattern recognition have been found by these companies to enhance both productivity and profit (Austin and Pisano, 2017). Still, the higher education system continues to lag behind, primarily framing neurodiversity as a disadvantage that must be overcome. Instead of building an inclusive learning environment, higher education systematically excludes many neurodiverse students from engineering and other STEM programs by perpetuating competitive environments that weed out all but those who easily fit into and succeed within traditional learning environments (Gasiewski et al., 2012). This systemic exclusion of neurodiverse learners severely limits the cognitive diversity of the future STEM workforce. A large number of anecdotal reports from neurodiverse individuals who succeeded as professionals despite dropping out of college suggest that the traditional educational system is often not conducive to the needs of the industry.

We argue that neurodiversity is a key aspect of human diversity that promises to enhance our collective potential to address increasingly complex engineering problems. This is supported by the emerging theory of complementary cognition, which suggests that neurological diversity within societies enhances adaptation through complementary search strategies that balance the need for both exploration of the unknown and use of known resources (Taylor et al., 2022). In other words, cognitive diversity allows humans to adapt at the group level by making use of multiple strategies that balance societal needs such as safety and risk-taking. Similarly, Chapman (2021) suggests that an ecological model of mental functioning allows us to take into account the ways in which individual neurocognitive variations contribute to human ecosystems and allow societies to persist and adapt (p. 1,365). This is in line with research that shows the multiple benefits that cognitive diversity has on team creativity (Hoever et al., 2012; Wang et al., 2016) and other performance measures such as system thinking and primary task performance (Sauer et al., 2006). In

these studies, cognitive diversity refers to perceived differences in thinking styles, knowledge, skills, values, and beliefs among team members (Van der Vegt and Janssen, 2003). By extension, creativity and innovation in society at large benefits from inclusion of neurodiverse members in the structures that contribute toward new knowledge. Thus, if neurodiverse learners are excluded from engineering and other STEM fields, society may not benefit from the full creative potential of our population.

To address this significant problem, a paradigm shift, i.e., a mindset shift, within higher education is necessary. In our view, a strengths-based approach toward neurodiversity incorporates an awareness of students' unique abilities rooted in biological/neurological variations, as well as an understanding that neurodiverse individuals are part of a complex human ecology that supports the ability of human populations to survive and thrive.

It is important to note at this early juncture in our conceptual analysis a borderline case, which must be considered. Specifically, while we are conceptualizing a strength-based paradigm for neurodiversity, we remain sensitive to the challenges and struggles of many students at all educational levels. We are fully aware of the needs of some individuals for targeted educational interventions and special education programs that may be essential to their success. However, we firmly believe that the majority of neurodiverse students in higher education programs will benefit most from an approach that emphasizes the assets and strengths associated with neurodiversity rather than one that solely focuses on the remediation of their perceived deficits.

In the following sections, we describe how neurodiversity is commonly pathologized in higher education and the barriers that screen out neurodiverse learners, especially within the context of engineering education. We then suggest some implications for engineering education and present our vision for a more inclusive learning environment that empowers neurodiverse students to thrive within the higher education system.

Neurodiversity in higher education—uses and model cases of the paradigm shift

The COVID-19 pandemic has resulted in more flexibility in the mode of instruction, with students having access to videos and lecture recordings in addition to the synchronous in person or remote lecture. In a survey of U.S. institutions that took place in April 2020, 65% of respondents provided access to recorded lectures and 51% to pre-recorded videos (Johnson et al., 2020); there is currently no statistically available data to what degree this practice continues. While the accessibility of such media is not guaranteed, the option to access content asynchronously can be life saving for neurodiverse students who may have challenges with focus, short-term information processing, and retention. In support of this notion, Madaus et al. (2021) reported that 46.6% of surveyed students that received accommodations prior to the pandemic reported no longer needing those because of increased content accessibility. The fluid dynamics of the COVID-19 environment create the institutional flexibility necessary to build a new educational approach, such as one conscious of the strength-based model within the engineering curriculum.

Considering such potential, this section aims to present a critical view of the current policies and practices of institutions of higher education in the context of neurodiversity and thus define the necessity and purpose of the strength-based model outlined in later sections. Clouder et al. (2020) present a review of studies detailing the neurodiverse college student experience and the prevalent conditions in higher education, painting a bleak view on both sides: on the student side, feelings of anxiety and marginalization, along with difficulty succeeding in the rigid academic setting of most programs; on the institutional side, haphazard provision of supports and judgmental attitudes by faculty. The study itself is perhaps a clear illustration of the current view of neurodiversity in academia: that of disability. Regardless of whether an institution provides higher levels of support, more resources or additional flexibility to neurodiverse students, in the best-case scenario, administrators, faculty, staff and students view neurodiversity fundamentally as impairment, which is turned into disability due to social attitudes and norms (i.e., the social model of disability) (Clouder et al., 2020). Institutions of higher education rely on centralized offices that more often than not include the term "disability" in their title (e.g., Center for Students with Disabilities, Disability Services, etc.). A survey of the Campus Disability Resource Database[1] indicates that out of 534 4-year HE institutions in the United States that provide information on disability services, 244 (46%) have the term "disability" in the title (National Center for College Students with Disabilities [NCCSD], 2022). A shift in terminology is controversial, as many believe this would erase and diminish the long history of the disability rights activism that made these centers possible. "Accessibility" is a term that has become more popular in recent years to alleviate the stigma associated with the disability label; 126 institutions (24%) used this term in the title of their respective office, as in The Center for Academic Success and Accessibility Services (CASAS, 2022) or The Student Accessibility and Academic Resource Center (StAAR, 2022). Regardless of terminology, this model has its roots in U.S. federal law, specifically the ADA. Disability (or accessibility) offices are the legally mandated institutions that ensure that reasonable accommodations are available to those who need and qualify for them. Their existence is thus critical

1 http://cedardatabase.org

in protecting the hard-won rights of marginalized groups of students.

Unwanted side effects of the existence of disability offices are that they may result in further marginalization and stigmatization of neurodiverse students who, in self-identifying as disabled, must mark themselves as different (Haft and Hoeft, 2021) and in complacency on the side of faculty and administrators who often simply follow the direction of the disability office's accommodations letter without further dialogue with the student or investigation of pedagogy that might better support student learning (Bettencourt et al., 2018). In the current model, instructors are only cognizant of the need to provide accommodations to students through a process that involves the separation of the students from their cohort, generally with little interaction or other forms of support provided by the instructor. The nature of accommodations is also such that faculty have no insight into the students' needs and challenges other than the specific accommodations prescribed by the disability office. The unique cognitive skills and talents of students are not recognized or communicated as a part of this process. Thus, there is little to no awareness with respect to neurodiversity, and whatever awareness exists is filtered through the disability lens.

At the administrative level, disability is programmatically separated from diversity, equity, and inclusion, and thus often excluded from organized efforts to promote DEI on college campuses. On the student side, this model also means that many students perceive an intense stigmatization from a process that separates them from their class and they are reluctant to seek accommodations or engage in discussions about their challenges (Cardoso et al., 2016; Weatherton and Mayes, 2017; Bettencourt et al., 2018; Kreider et al., 2018). Additionally, bias against neurodiverse students among disability services providers may further impact students' ability to access accommodations. For example, a recent study found evidence that service providers ranked students with ADHD as less deserving of accommodations due to negative perceptions of their work ethic (Druckman et al., 2021). In some institutions the out-of-pocket costs associated with the screening needed for registration with these disability services amounts to a significant portion of the college expenses. This prohibitive cost widens the accessibility gap and turns these accommodations into a privilege that is only afforded to families with the available financial resources (Powell, 2016). Finally, disability services are almost exclusively geared toward mitigating perceived impairments, with little or no discussion on how students or instructors can make changes to capitalize on student strengths; it is inherently and overwhelmingly a deficit-based approach (Pickard, 2021).

The level of accommodations needed to support the success of neurodiverse students depends on the rigidity of the education process itself; the more inflexible the classroom environment, the more accommodations are needed. While higher education provides greater flexibility in structuring the learning experience compared to K-12, it is often shaped following the traditional model of lecture and exam, especially in STEM disciplines. The majority of large engineering programs in the United States are located within public universities, have long history and traditions, and opt to be accredited by the ABET Engineering Accreditation Commission (as is the case with the program to which the authors belong). In 2019, 334,984 students (54% of total in the United States) were enrolled in the top 50 universities with the highest enrollments (>4,235), 46 of these institutions were public and all 50 had the majority of their engineering programs accredited by ABET (ASEE, 2021). These factors further encourage a highly structured and prescribed educational experience, leaving little room for neurodiverse students to shape their learning and to bring their unique cognitive assets to the educational environment, for example, by exploring electives that leverage special interest areas or unique skills (Winter-Messiers et al., 2007; Meilleur et al., 2015), creativity (White and Shah, 2011; Taylor and Zaghi, 2021), or entrepreneurial mindset (Moore et al., 2021).

Uses of the strength-based concept

Engineering curricula, especially in traditional disciplines that have the highest student enrollments (mechanical, civil, computer science, and engineering), are shaped both by ABET and the professional societies that elaborate further on the broad curriculum requirements of ABET Criterion 5 (30 credits of math and science, 45 credits of engineering, general education, and major design experience). Given that the minimum number of credits for an engineering degree is 120, this means that typically, at least 100 credits are needed to fulfill these general requirements. In the civil engineering program at our institution, for example, students have 7 elective credits out of 128. The coursework demands of the engineering curriculum makes it challenging for students to explore the opportunities of creative minors; pursuing entrepreneurship, or simply taking courses beyond the expected course sequence, is often challenging for engineering students who might thrive if given the opportunity to think outside of the box. As such, below we identify three potential use cases for the strength-based model within a revised engineering curriculum.

Use 1: Class size

A high number of required courses and large enrollments in the most popular disciplines (mechanical, computer science, and civil engineering) also pose constraints on course offerings and delivery mechanisms. The majority of the universities with the highest engineering enrollments are not only public, but also have an R1 Carnegie classification (42 out of 50). This

means that tenure-track faculty in these institutions have a split workload between teaching and research, and the reward structure for promotion and tenure is heavily skewed toward research productivity. The lack of adequate preparation for effective teaching and student engagement by engineering faculty who were trained as graduate students in R1 institutions themselves has been extensively documented (Buswell, 2021). The inevitable outcome is that the large lecture format is the prevalent course delivery modality, especially in the sophomore and junior years, and that the number of flexible, innovative courses that can be offered to engineering students is small.

The effect of class size is much debated in the literature, and it is beyond the scope of this article to provide a comprehensive discussion of it. Here, we adopt the definitions of Kara et al. (2021) in terms of class size, with a small class having fewer than 30 students, while a large class exceeds 100 students in size. Kokkelenberg et al. (2008) showed that the largest effect of class size on student performance as measured by grades occurred up to about 20–40 students. Kara et al. (2021) further investigated the effect distinguishing between STEM and non-STEM disciplines and reported that reducing class size from very large (>163) to large (100∼150) could have a statistically significant effect on student performance. They also reported that the negative effects of larger classes were stronger for students of disadvantaged backgrounds. Ake-Little et al. (2020) reported that positive effects of smaller class sizes (<40) were only observed for white and Asian/Pacific Islander males in STEM disciplines, with lack of mentorship. However, these authors observed no negative impact of bigger class sizes on any group, which they attribute to changes in the instructional mode. As the authors state: "A class size between 31 and 40 may well be the maximum limit before an instructor is forced to incorporate more timesaving, but less academically meaningful assignments (e.g., curtailing the number of assigned papers or eliminating time-intensive projects) to the detriment of student learning and, ultimately, student achievement" (p. 602). This observation is particularly relevant to neurodiverse students, who experience a double negative impact due to the inherent anonymity in a large class and the reliance on traditional modes of instruction and assessment in these classes; instructors of large classes may not have time to personalize the learning environment according to the abilities of individual students or to incorporate innovative pedagogies that might enhance learning for a wider range of learners.

Use 2: Assessment

Changes in the mode of assessment as a result of emergency remote teaching are more difficult to evaluate in terms of aiding or further burdening neurodiverse students. While 93% of respondents to a 2020 survey of institutions of higher education by the National Institute for Learning Outcomes assessment reported at least one change in assessment (such as modification of assignments, flexible deadlines, or shifting to pass/fail), and 63% more than one change, there was no consistency in the types, combinations, and perceptions of the impact of these changes (Jankowski, 2020). Some changes, such as acceptance of alternative assessments and flexibility in deadlines, are likely to have supported neurodiverse students (Johnson et al., 2020) while others, such as moving to multiple-choice quizzes and using timed, online proctored exams, are more likely to have placed additional burden. Extended time and reduced distraction were the most common accommodations that students obtained even during the pandemic (Madaus et al., 2021), highlighting the disproportionate burden tests place on neurodiverse students. Increased flexibility and more empathy with students are side effects of the pandemic (Jankowski, 2020) that, if they persist, will be beneficial to neurodiverse students. Another positive impact of the pandemic is a shift of faculty attitudes toward students and their unique challenges. Faculty reported that they felt compelled to address personal situations such as health and family issues and to reach out to students who were struggling. Now, as the intensity of the pandemic wanes, it is important to consider how engineering departments may avoid reverting to default pre-pandemic culture, practices and attitudes.

Use 3: Dissuading negative competition

STEM disciplines, and particularly engineering, are known for their competitive culture, starting early with so called "weed out" courses, most frequently foundational math and science courses. These classes not only result in directly causing students to switch out of STEM, but also have negative consequences for those who choose to stay (Weston et al., 2019). While there is no data explicitly to the effect of weed out courses on neurodiverse students, studies have shown that there are disproportionate consequences on women and minorities, i.e., marginalized groups. Faculty attitudes that view accommodations as unfair advantages are also features of this culture (Lombardi and Murray, 2011; Bettencourt et al., 2018). Finally, there is a distinct lack of representation when it comes to neurodiverse faculty as role models; even faculty who privately identify as neurodiverse have little incentive to have open discussions with students. It is the experience of the authors that such discussions can have a profound effect on students struggling with their identity and feelings of "not being good enough." Every student deserves to feel included and be offered opportunities for growth in an educational environment. To achieve that goal for all students, there is an urgent need for shifting the focus from the current rigid, overly standardized education system to a

fundamentally inclusive system that integrates unique assets of non-traditional learners inside and outside the classroom. While we acknowledge that there are existing paradigms for flexible, inclusive higher education, they are typically available to the select few who have the means to attend the small, private institutions that can provide such an environment. The higher education system requires transformation at a larger scale to serve a broader audience, encourage the emergence of creative solutions for the large-scale technical challenges facing our nation, and create a professional workforce that is representative of the diversity of our society.

Moving forward/the next frontier–A model case for the strength-based concept

In this section, we propose a blueprint to model a transformative higher education system. We recognize that some of the proposed transformations demand a cultural shift that may not be immediately attainable; however, steady progress toward the implementation of fundamental changes is possible. The basic rationale for the proposed initiatives is discussed below along with some initial ideas for their implementation.

Raise awareness around power dynamics and foundational biases of the current education system

The current education system is designed by and for neurotypical individuals. This often results in a power dynamic that puts neurodiverse learners at a disadvantage. This imbalance is further perpetuated by many assumptions that are often not true for neurodiverse learners. For example, the traditional education system often assumes that all learners must be able to acquire knowledge from textual information and communicate their ideas in written format. Furthermore, it often relies on linear learning of information and fails to acknowledge the importance of alternative ways of acquiring knowledge such as experimentation and exploration. Similarly, the traditional education system often places undue emphasis on standardized tests and evaluation methods, which may fail to assess the learning of neurodiverse individuals. For example, dyslexic students who struggle with the written format of traditional exams may better demonstrate their learning if given the opportunity to demonstrate engineering concepts through alternate means that use their individual strengths, such as visual expression, oral presentation, or three-dimensional modeling (Griffin and Pollak, 2009; Robinson, 2017; Rappolt-Schlichtmann et al., 2018). To move toward a more inclusive education system, it is essential to be aware of the power dynamics and foundational biases of the current education system. The values and assumptions of the engineering education system (that all good engineers must have strengths in written communication, social interactions, and organization) are carried on by faculty in positions of power, thus propagating a system that privileges certain modes of communication and interaction over others and weeding out those whose strengths lie elsewhere. It is also important to acknowledge the intersectional nature of larger societal power dynamics as we consider neurodiverse students whose lived experiences lie at the intersection of multiple marginalized identities, such as neurodiverse students from diverse racial and ethnic backgrounds and LGBTQIA+students.

Focus on developing learners' strengths and skills within an individualized learning framework

A strength-based approach may lead to improved academic performance, increased motivation, and higher levels of engagement in the learning process (Louis, 2011; Schreiner, 2014) and a focus on strengths may be particularly useful for neurodiverse students who have been subjected to a primarily deficit-focused system (Winter-Messiers et al., 2007; Armstrong, 2012; Rappolt-Schlichtmann et al., 2018). It is essential to develop a more individualized approach to education that considers the unique strengths and interests of each learner. We need to ensure that our assessment practices are just and fair for diverse learners with unique challenges and skills. For example, a writing assignment in a technical course could put individuals with dyslexia at a significant disadvantage as compared to their peers. A more inclusive assessment practice would be to provide an opportunity for the learner to submit an audio or video recording of the same assignment. The need for all of these may be eliminated if Universal Design for Learning (UDL) principles are systematically integrated in all courses, as argued by Clouder et al. (2020) and others. The application of even a limited subset of UDL guidelines, such as the use of accessible content, multiple modes of communication, and flexibility in the types of assignments and assessments, can be powerful ways of building an inclusive learning environment.

Promote a practice shift from a deficit-focused medical model to an empowerment model

The traditional education system often relies on a medical model approach that views learners with diagnosed disabilities

as patients in need of treatment. This approach often leads to negative labels and stereotypes that can further impair the academic and social development of these learners. In contrast, empowerment theory suggests that all learners may be encouraged to leverage their individual differences to take ownership of their learning within an inclusive and supportive educational environment (Perkins and Zimmerman, 1995). This approach can help learners form positive identities, build self-esteem and self-advocacy, and develop a sense of belonging within the educational community (Zimmerman, 1995). Bringing neurodiversity to the forefront, and encouraging a positive narrative around it, is a crucial step toward achieving this goal. This issue needs to be addressed at multiple levels. At the student and faculty level, a more extensive awareness of and exposure to the emerging theories around cognitive diversity may be a powerful tool to facilitate the mindset shift; changes in attitude and approach at the individual faculty level may have a profound impact on the experience of neurodiverse students within these courses. At the institution level, providing faculty development opportunities that emphasize a strengths-based approach to neurodiversity, adopting a more equitable admission process and employing strengths-based language that emphasizes diversity rather than deficit, in education settings, such as in a classroom environment, are expected to play a critical role in promoting this culture shift.

Increase the representation of neurodiverse individuals in the faculty

It is critical to be aware that higher (and especially graduate) education systems and recruitment practices are heavily biased toward individuals with exceptional written communication skills and those who perform well on standardized tests and assessments. These biases limit the talent pool and the perspectives that inform our teaching practices and curricular design. It is therefore essential to critically evaluate our traditional faculty recruitment practices and to make a concerted effort to increase the representation of high potential, non-traditional learners in the faculty body. Without the involvement of individuals with lived experience of neurodiversity, it will be difficult, or even impossible, to develop an understanding of the challenges and needs of this population. In addition, the lack of representation of their perspective in education policy making and curricular design activities leads to further distancing from truly inclusive education practices. In addition, neurodiverse faculty can play a critical role in empowering learners as role models. However, neurodiversity as an invisible form of diversity requires openness on the part of the faculty to promote discussions around this topic in a classroom or during individual interactions with students.

Value and celebrate individual differences as an indispensable asset for the creativity of the professional workforce

Several studies have shown that the most innovative teams were those in which individuals with a variety of viewpoints, experiences, and cognitive skills were present, i.e., teams that were as diverse as possible (McLeod et al., 1996; Milliken and Martins, 1996; Ragins, 2004). A neurodiverse team is better positioned to solve complex problems. It is therefore essential to move away from an education system that values only individual originality and expand the definition of creativity to include group creativity. To achieve this, the system must be aware of the need to create a more inclusive environment that allows the team's collective intelligence to flourish. In a classroom setting, moving toward a broader adoption of team-based assessments, with student training, may facilitate the cultivation of both individual strengths and team creativity.

Encourage the effective use of emerging technologies, in particular artificial intelligence, to support a more inclusive learning environment

The traditional education system has been designed around a one-to-many teaching practice that is becoming less effective, as it is unable to fully address the needs and cultivate the strengths of a diverse group of learners. Emerging technologies, in particular artificial intelligence (AI) and natural language processing (NLP), can be used to create a more customized and individualized learning environment that will support the unique ways of thinking and learning of neurodiverse students. For example, artificial intelligence may be used to customize textual information and educational material, assess learners' strengths and weaknesses in a more personalized manner and design individualized intervention programs to help learners develop their strengths and skills. This presents significant opportunities in research and development of these technologies through the collaboration of multiple disciplines.

Summary

In summary, we argue that the perception of neurodiversity as a deficit, along with the overreliance on traditional pedagogical methods in engineering courses, is severely limiting both the participation of neurodiverse students in engineering fields and the creativity of the national engineering workforce. It also places an undue psychological and financial burden on families that require additional resources to support

neurodiverse student success, creating an often hidden but substantial equity issue. To enhance the creative potential of the next generation of engineers, a paradigm shift in engineering education is sorely needed. We believe that a shift from a deficit perspective to a strengths-based model has the potential to empower students to leverage their individual strengths, while also reducing the suffering of neurominority students who have been marginalized by an education system designed to meet the needs of the neurotypical majority.

Beyond engineering education, we believe that the higher education system has the potential to provide transformative learning experiences for all students; to do so, significant and sustained cultural change is needed. Institutions of higher education must examine and disrupt the power dynamics and foundational biases present within the current system, provide personalized education experiences that cultivate learners' strengths and interests, move away from the current focus on student deficits, and embrace an empowerment model to enhance students' sense of belonging. We envision a paradigm shift in which institutions of higher learning promote and celebrate individual differences as an indispensable asset for the creativity of the professional workforce, put forth dramatic changes in hiring practices to increase the representation of neurodiverse individuals in the faculty body, involve them in education policy making and curricular design activities, and encourage the effective use of emerging technologies, in particular artificial intelligence, to support a more inclusive and personalized learning environment.

Author contributions

MC provided the analysis of neurodiversity in higher education and uses of the strengths-based approach. AZ drafted the model case for a strength-based concept. CS performed the literature review. All authors contributed to the final manuscript.

Funding

This material was based upon work supported by the National Science Foundation under IUSE/PFE:RED Grant No. 1920761. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Acknowledgments

We thank Alexander Grey for his contribution to the structure of this conceptual analysis.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Ake-Little, E., von der Embse, N., and Dawson, D. (2020). Does class size matter in the university setting? *Educ. Rese.* 49, 595–605. doi: 10.3102/0013189X20933836

Armstrong, T. (2012). First, discover their strengths. *Educ. Leadership* 70:10.

Armstrong, T. (2017). Neurodiversity: the future of special education? *Educ. Leadership* 74, 10–16.

ASEE (2021). *Engineering & Engineering Technology By the Numbers*. Washington, DC: ASEE.

Attree, E. A., Turner, M. J., and Cowell, N. (2009). A virtual reality test identifies the visuospatial strengths of adolescents with dyslexia. *Cyberpsychol. Behav.* 12, 163–168. doi: 10.1089/cpb.2008.0204

Austin, R. D., and Pisano, G. P. (2017). Neurodiversity as a competitive advantage. *Harvard Bus. Rev.* 95, 96–103.

Barnard-Brak, L., Lechtenberger, D., and Lan, W. Y. (2010). Accommodation strategies of college students with disabilities. *Qual. Rep.* 15:411.

Baumol, W. J. (2005). Education for innovation: entrepreneurial breakthroughs versus corporate incremental improvements. *Innov. Policy Econ.* 5, 33–56. doi: 10.1086/ipe.5.25056170

Bettencourt, G., Kimball, E., and Wells, R. S. (2018). Disability in postsecondary STEM learning environments: what faculty focus groups reveal about definitions and obstacles to effective support. *J. Postsecondary Educ. Disabil.* 31, 383–396.

Bouvet, L., Mottron, L., Valdois, S., and Donnadieu, S. (2016). Auditory stream segregation in autism spectrum disorder: benefits and downsides of superior perceptual processes. 46, 1553–1561. doi: 10.1007/s10803-013-2003-8

Braun, V., and Clarke, V. (2022). *Thematic Analysis: A Practical Guide*. Los Angeles, CA: SAGE.

Brown, H. M., Stahmer, A. C., Dwyer, P., and Rivera, S. (2021). Changing the story: how diagnosticians can support a neurodiversity perspective from the start. *Autism* 25, 1171–1174. doi: 10.1177/13623613211001012

Buswell, N. T. (2021). The purpose of a PhD in engineering: where does teaching fit in? *Stud. Eng. Educ.* 1, 83–96. doi: 10.21061/see.8

Cardoso, E. D. S., Phillips, B. N., Thompson, K., Ruiz, D., Tansey, T. N., and Chan, F. (2016). Experiences of minority college students with disabilities in STEM. *J. Postsecondary Educ. Disabil.* 29, 375–388.

CASAS (2022). *Center for Academic Success and Accessibility Services (CASAS)*. Available online at: https://inside.southernct.edu/casas (accessed Sept 9, 2022).

Chapman, R. (2021). Neurodiversity and the social ecology of mental functions. *Perspect. Psychol. Sci.* 16, 1360–13722. doi: 10.1177/1745691620959833

Clouder, L., Karakus, M., Cinotti, A., Ferreyra, M. V., Fierros, G. A., and Rojo, P. (2020). Neurodiversity in higher education: a narrative synthesis. *Higher Educ.* 80, 757–778. doi: 10.1007/s10734-020-00513-6

Cortiella, C., and Horowitz, S. H. (2014). *The State of Learning Disabilities: Facts, Trends and Emerging Issues*. New York, NY: National Center for Learning Disabilities.

Crespi, B. (2021). Pattern unifies autism. *Front. Psychiatry* 12:621659. doi: 10.3389/fpsyt.2021.621659

Daniels, S., and Freeman, M. (2018). "Gifted dyslexics: MIND-strengths, visual thinking, and creativity," in *Twice Exceptional: Supporting and Educating Bright and Creative Students with Learning Difficulties*, ed. S. B. Kaufman (Oxford: Oxford University Press).

den Houting, J. (2019). Neurodiversity: an insider's perspective. *Autism* 23, 271–273. doi: 10.1177/1362361318820762

Diehl, J. J., Frost, S. J., Sherman, G., Mencl, W. E., Kurian, A., Molfese, P., et al. (2014). Neural correlates of language and non-language visuospatial processing in adolescents with reading disability. *Neuroimage* 101, 653–666. doi: 10.1016/j.neuroimage.2014.07.029

Dinishak, J. (2016). The deficit view and its critics. *Disability Stud. Quarterly* 36. doi: 10.18061/dsq.v36i4.5236

Doyle, N. (2020). Neurodiversity at work: a biopsychosocial model and the impact on working adults. *Br. Med. Bull.* 135, 108–125. doi: 10.1093/bmb/ldaa021

Druckman, J. N., Levy, J., and Sands, N. (2021). Bias in education disability accommodations. *Econ. Educ. Rev.* 85:102176. doi: 10.1016/j.econedurev.2021.102176

Dwyer, P. (2022). The neurodiversity Approach(es): what are they and what do they mean for researchers? *Hum. Dev.* 66, 73–92. doi: 10.1159/000523723

Ehlinger, E., and Ropers, R. (2020). It's all about learning as a community: facilitating the learning of students with disabilities in higher education classrooms. *J. College Student Dev.* 61, 333–349. doi: 10.1353/csd.2020.0031

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., and Chang, M. J. (2012). From gatekeeping to engagement: a multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Res. Higher Educ.* 53, 229–261. doi: 10.1007/s11162-011-9247-y

Goegan, L. D., and Harrison, G. L. (2017). The effects of extended time on writing performance. *Learn. Disabil.* 15:209.

Golter, P. B., Thiessen, D. B., Van Wie, B. J., and Brown, G. R. (2012). Adoption of a non-lecture pedagogy in chemical engineering: insights gained from observing an adopter. *J. STEM Educ.* 13:52.

Griffin, E., and Pollak, D. (2009). Student experiences of neurodiversity in higher education: insights from the BRAINHE project. *Dyslexia* 15, 23–41. doi: 10.1002/dys.383

Haft, S., and Hoeft, F. (2021). A meta-analytic review of the consequences of stigma and stereotype threat for individuals with specific learning disabilities. *PsyArXiv [preprint]* doi: 10.31234/osf.io/bt7ew

Haney, J. L. (2018). Reconceptualizing Autism: an alternative paradigm for social work practice. *J. Prog. Hum. Services* 29, 61–80. doi: 10.1080/10428232.2017.1394689

Hoever, I. J., van Knippenberg, D., van Ginkel, W. P., and Barkema, H. G. (2012). Fostering team creativity: perspective taking as key to unlocking diversity's potential. *J. Appl. Psychol.* 97, 982–996. doi: 10.1037/a0029159

Jankowski, N. A. (2020). Reflecting on COVID-19 and the future of assessment. *Assessment Update* 32, 12–13. doi: 10.1002/au.30237

Johnson, N., Veletsianos, G., and Seaman, J. (2020). U.S. faculty and administrators' experiences and approaches in the early weeks of the COVID-19 pandemic. *Online Learn. J.* 24, 6–21. doi: 10.24059/olj.v24i2.2285

Kara, E., Tonin, M., and Vlassopoulos, M. (2021). Class size effects in higher education: differences across STEM and non-STEM fields. *Econ. Educ. Rev.* 82:102104. doi: 10.1016/j.econedurev.2021.102104

Kazerounian, K., and Foley, S. (2007). Barriers to creativity in engineering education: a study of instructors and students perceptions. *J. Mech. Des.* 129, 761–768. doi: 10.1115/1.2739569

Kokkelenberg, E., Dillon, M., and Christy, S. (2008). The effects of class size on student grades at a public university. *Econ. Educ. Rev.* 27, 221–233. doi: 10.1016/j.econedurev.2006.09.011

Kreider, C. M., Medina, S., Lan, M., Wu, C., Percival, S. S., Byrd, C. E., et al. (2018). Beyond academics: a model for simultaneously advancing campus-based supports for learning disabilities, STEM students' skills for self-regulation, and mentors' knowledge for co-regulating and guiding. *Front Psychol.* 9:1466. doi: 10.3389/fpsyg.2018.01466

Lambert, R. (2018). "Indefensible, Illogical, and Unsupported"; countering deficit mythologies about the potential of students with learning disabilities in mathematics. *Educ. Sci.* 8:72. doi: 10.3390/educsci8020072

Lombardi, A. R., and Murray, C. (2011). Measuring university faculty attitudes toward disability: willingness to accommodate and adopt Universal Design principles. *J. Vocational Rehabilitation* 34, 43–56. doi: 10.3233/JVR-2010-0533

Louis, M. C. (2011). Strengths interventions in higher education: the effect of identification versus development approaches on implicit self-theory. *J. Positive Psychol.* 6, 204–215. doi: 10.1080/17439760.2011.570366

Madaus, J. W., Gelbar, N., Faggella-Luby, M., and Dukes, L. L. III (2021). Experiences of students with disabilities during the COVID-19 interruption of in-person instruction. *J. Postsecondary Educ. Disabil.* 34, 5–18.

Martin, J. K., Stumbo, N. J., Martin, L. G., Collins, K. D., Hedrick, B. N., Nordstrom, D., et al. (2011). Recruitment of students with disabilities: exploration of science, technology, engineering, and mathematics. *J. Postsecondary Educ. Disabil.* 24, 285–299.

McCarron, E. C. (2017). *The Willingness and Ability of Postsecondary Faculty to Provide Academic Accommodations to Students With Disabilities*. PhD thesis, Beverly, MA: Endicott College.

McLeod, P. L., Lobel, S. A., and Cox, T. H. (1996). Ethnic diversity and creativity in small groups. *Small Group Res.* 27, 248–264. doi: 10.1177/1046496496272003

Meilleur, A. S., Jelenic, P., and Mottron, L. (2015). Prevalence of clinically and empirically defined talents and strengths in Autism. *J. Autism Dev. Disord.* 45, 1354–1367. doi: 10.1007/s10803-014-2296-2

Milliken, F. J., and Martins, L. L. (1996). Searching for common threads: understanding the multiple effects of diversity in organizational groups. *Acad. Manage.* 21, 402–433. doi: 10.2307/258667

Moon, N. W., Todd, R. L., Morton, D. L., and Ivey, E. (2012). *Accomodating Students with Disabilities in Science, Technology, Engineering, and Mathematics (STEM): Findings from Research and Practice for Middle Grades through University Education, SciTrain*. Atlanta, GA: Science and Math for All.

Moore, C. B., McIntyre, N. H., and Lanivich, S. E. (2021). ADHD-Related neurodiversity and the entrepreneurial mindset. *Entrepreneurship Theory Practice* 45, 64–91. doi: 10.1177/1042258719890986

Mottron, L. (2011). Changing perceptions: the power of autism. *Nature* 479, 33–35. doi: 10.1038/479033a

National Center for College Students with Disabilities [NCCSD] (2022). *CeDaR*. Available online at: https://www.cedardatabase.org/ (accessed September 9, 2022).

Perkins, D. D., and Zimmerman, M. A. (1995). Empowerment theory, research, and application. *Am. J. Community Psychol.* 23, 569–579. doi: 10.1007/BF02506982

Pickard, B. (2021). A framework for mediating medical and social models of disability in instrumental teaching for children with down syndrome. *Res. Stud. Music Educ.* 43, 110–128. doi: 10.1177/1321103X19855416

Powell, F. (2016). *Plan for Greater College Costs for Students with Learning Disabilities*. New York, NY: U.S. News and World Report, L.P.

Ragins, B. R. (2004). "Sexual orientation in the workplace: the unique work and career experiences of gay, lesbian and bisexual workers," in *Research in Personnel and Human Resources Management*, ed. J. J. Martocchio (Amsterdam: Elsevier Science/JAI Press).

Rappolt-Schlichtmann, G., Boucher, A. R., and Evans, M. (2018). From deficit remediation to capacity building: learning to enable rather than disable students with Dyslexia. *Lang. Speech Hear. Serv. Sch.* 49, 864–874. doi: 10.1044/2018_LSHSS-DYSLC-18-0031

Robinson, S. A. (2017). Phoenix rising: an autoethnographic account of a gifted black male with Dyslexia. *J. Educ. Gifted* 40, 135–151. doi: 10.1177/0162353217701021

Russell, G. (2020). "Critiques of the neurodiversity movement," in *Autistic Community and the Neurodiversity Movement: Stories from the Frontline*, ed. S. K. Kapp (Singapore: Palgrave Macmillan). doi: 10.1007/978-981-13-8437-0_21

Sauer, J., Felsing, T., Franke, H., and Rüttinger, B. (2006). Cognitive diversity and team performance in a complex multiple task environment. *Ergonomics* 49, 934–954. doi: 10.1080/00140130600577502

Schreiner, L. A. (2014). "Strengths-Oriented teaching: pathways to engaged learning," in *Paths to Learning: Teaching for Engagement in College*, ed. B. F. Tobolowsky (Columbia: University of South Carolina, National Resource Center for the First-Year Experience and Students in Transition).

Singer, J. (1998). *Odd People in: The Birth of Community Amongst People on the Autistic Spectrum. A Personal Exploration Based on Neurological Diversity*. Sydney: University of Technology.

Smith, S. A., Woodhead, E., and Chin-Newman, C. (2021). Disclosing accommodation needs: exploring experiences of higher education students with disabilities. *Int. J. Inclusive Educ.* 25, 1358–1374. doi: 10.1080/13603116.2019.1610087

Sparks, R. L., Javorsky, J., and Philips, L. (2004). College students classified with ADHD and the foreign language requirement. *J. Learn. Disabil.* 37, 169–178. doi: 10.1177/00222194040370020701

StAAR (2022). *About the StAAR center*. Available online at: https://students.tufts.edu/staar-center/about/about-staar-center (accessed September 9, 2022).

Taylor, C. L., and Zaghi, A. E. (2021). The nuanced relationship between creative cognition and the interaction between executive functioning and intelligence. *J. Creat. Behav.* 55, 857–874. doi: 10.1002/jocb.493

Taylor, C. L., Zaghi, A. E., Kaufman, J. C., Reis, S. M., and Renzulli, J. S. (2020). Characteristics of ADHD related to executive function: differential predictions for creativity-related traits. *J. Creat. Behav.* 54, 350–362. doi: 10.1002/jocb.370

Taylor, H., Fernandes, B., and Wraight, S. (2022). The evolution of complementary cognition: humans cooperatively adapt and evolve through a system of collective cognitive search. *Cambridge Archaeol. J.* 32, 61–77. doi: 10.1017/S0959774321000329

Van der Vegt, G., and Janssen, O. (2003). Joint impact of interdependence and group diversity on innovation. *Creat. Innovation* 29, 729–751. doi: 10.1016/S0149-2063_03_00033-3

von Karolyi, C. (2001). Visual-Spatial strength in dyslexia: rapid discrimination of impossible figures. *J. Learn. Disabil.* 34, 380–391. doi: 10.1177/002221940103400413

Walker, L., and Avant, K. (2005). *Strategies for Theory Construction in Nursing*. Norwalk: Appleton & Lange.

Walker, L. O., and Avant, K. C. (1995). "Concept development" in strategies for theory construction," in *Nursing*, 3rd Edn, eds L. O. Walker and K. C. Avant (Norwalk: Appleton & Lange).

Wang, X., Kim, T., and Lee, D. (2016). Cognitive diversity and team creativity: effects of team intrinsic motivation and transformational leadership. *J. Bus. Res.* 69, 3231–3239. doi: 10.1016/j.jbusres.2016.02.026

Weatherton, Y. P., and Mayes, R. D. (2017). "Barriers to persistence for engineering students with disabilities," in *Proceedings of the American Society for Engineering Education Annual Conference and Exposition*, (Columbus, OH).

Wei, X., Yu, J. W., Shattuck, P., and Blackorby, J. (2017). High school math and science preparation and postsecondary STEM participation for students with an autism spectrum disorder. *Focus Autism Other Dev. Disabil.* 32, 83–92. doi: 10.1177/1088357615588489

Weston, T. J., Seymour, E., Koch, A. K., and Drake, B. M. (2019). "Weed-Out classes and their consequences," in *Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*, eds E. Seymour and A. Hunter (Cham: Springer). doi: 10.1007/978-3-030-25304-2

White, H. A., and Shah, P. (2006). Uninhibited imaginations: creativity in adults with attention-deficit/hyperactivity disorder. *Personal. Individual Differ.* 40, 1121–1131. doi: 10.1016/j.paid.2005.11.007

White, H. A., and Shah, P. (2011). Creative style and achievement in adults with attention-deficit/hyperactivity disorder. *Personal. Individual Differ.* 50, 673–677. doi: 10.1016/j.paid.2010.12.015

White, H. A., and Shah, P. (2016). Scope of semantic activation and innovative thinking in college students with ADHD. *Creat. Res. J.* 28, 275–282. doi: 10.1080/10400419.2016.1195655

Winter-Messiers, M. A., Herr, C. M., Wood, C. E., Brooks, A. P., Gates, M. A. M., Houston, T. L., et al. (2007). How far can brian ride the daylight 4449 express? a strength-based model of asperger syndrome based on special interest areas. *Focus Autism Other Dev. Disabil.* 22, 67–79. doi: 10.1177/1088357607022002070l

Zaghi, A. E., Reis, S. M., Renzulli, J. S., and Kaufman, J. C. (2016). "Unique potential and challenges of students with ADHD in engineering programs," in *Proceedings of the 2016 ASEE Annual Conference & Exposition*, (New Orleans, LA).

Zimmerman, M. A. (1995). Psychological empowerment: issues and illustrations. *Am. J. Community Psychol.* 2, 581–599. doi: 10.1007/BF02506983